MULTI-DIMENSIONAL GRAPHICAL REPRESENTATION FOR ANALYZING VARIATION IN QUANTITATIVE CHARACTERS

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A basic difficulty in analyzing data on species crosses is that the mind is ordinarily incapable of comprehending the simultaneous occurrence of variation in several different characters. In studying the results of a cross between *Nicotiana Langsdorfii* and *N. alata*, the authors developed a graphical method for analyzing the variation in four distinct characters considered together.

The four characters used are all measured in the flower, for, as East pointed out in a classic paper on the subject[1], floral dimensions are better than vegetative

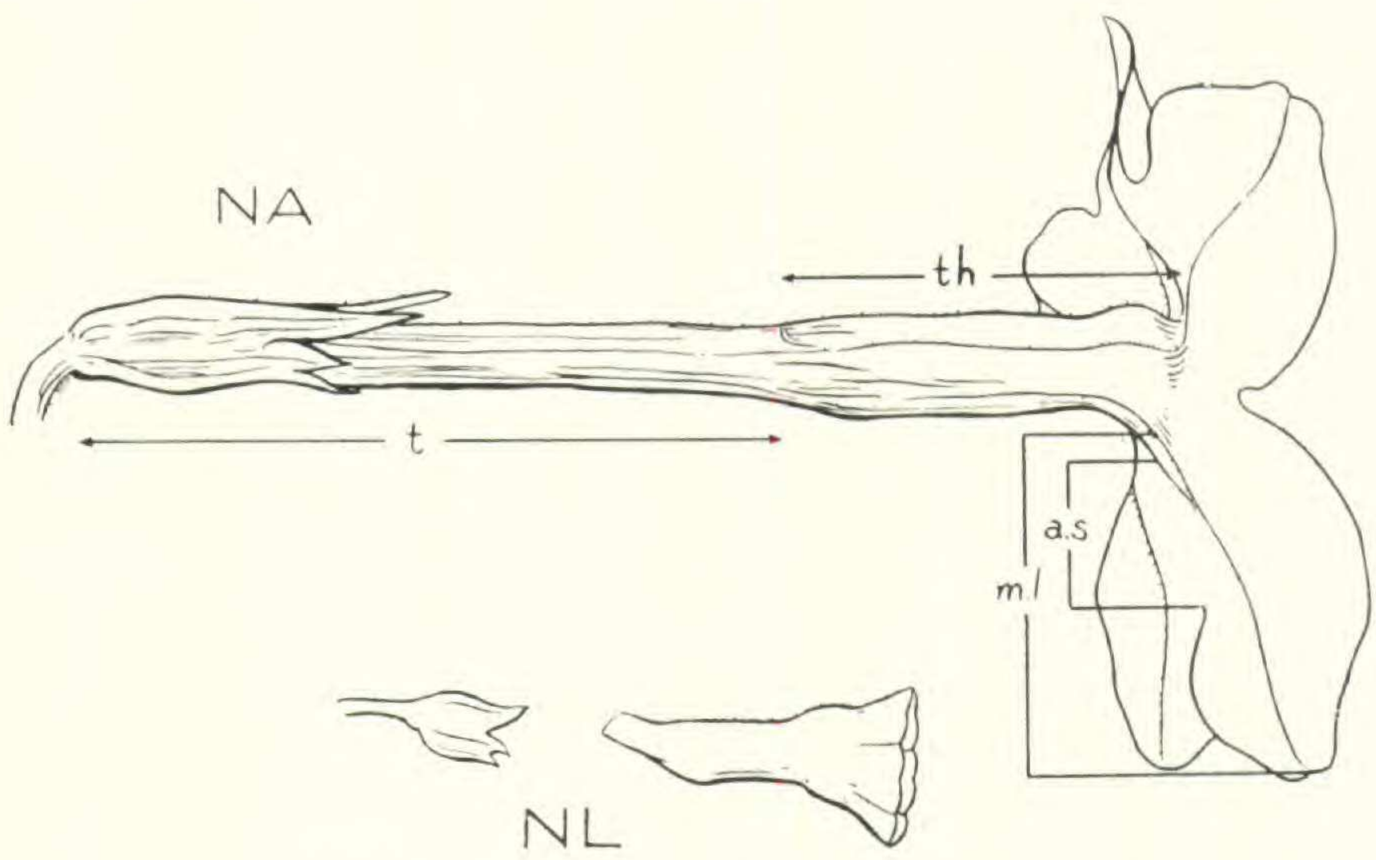

Fig. 1. Flowers of *Nicotiana alata* (NA) and *N. Langsdorfii* (NL): *t* — tube, *th* — throat, *ml* — maximum lobe, *as* — adjacent sinus.

parts for studies of so-called quantitative characters and measurements. These four characters are: the length of throat, maximum lobe, adjacent sinus[2], and tube (fig. 1), each one being expressed by a different dimension of a fourth-dimensional figure. Thus, the length of the throat is the length of the horizontal, or first dimension; maximum lobe, the vertical or second dimension; adjacent sinus, the third dimension; and tube, the fourth. A fourth-dimensional picture of each generation—the two parents, *Nicotiana Langsdorfii* (NL) and *N. alata* (NA), the F-1 generation (NLA), and two sister families of the F-2 (NLALA-b

[1] East, E. M. Significant accuracy in recording genetic data. Amer. Jour. Bot. **3**:211-222. 1916.
[2] Smith, Harold H. The relation between genes affecting size and color in certain species of *Nicotiana*. Genetics **22**:361-375. 1937.

and NLALA-g)—is obtained by using the group's median measurements of each character. To permit accurate comparison, the same scales and angles of slope are used throughout.

As may be seen in fig. 2, extreme dissimilarities in size and shape occur in the parent species, NL and NA, which differ significantly in all six ratios. The greatest difference in proportions is due to the throat being the longest absolute dimension in NL, and the tube longest in NA.

The F-1 and F-2 generations occupy an intermediate position between NL and NA, with the F-1 exhibiting the effects of hybrid vigor by its slightly larger size (very nearly proportionately so) than the F-2. The intermediate condition of the F-1's and F-2's is further emphasized by the approximately equal lengths of tube and throat. The individuals of any F-2 between two very unlike parents will be segregating for various characters which will affect survival differentially, even under experimental conditions. There will be susceptibility to various diseases and environmental conditions—in this case wilt and mosaic, crowding in the seed-pan, survival during cloudy weather in short days of winter, etc. Besides supplying a means for comparing the F-1 and F-2 generations, this graphical method permits the comparison of the F-2's in successive years to obtain an average.

This multi-dimensional representation not only allows the mind to conceive the effects of more than one character at a time, but also permits analysis of just those characters considered, excluding those characters which may, in analyses using the actual flower, cause optical illusions and distracting effects. Additional and more detailed comparisons may be made from the figures—such as variation in actual size of one particular character, the effect of similarity in size of two or three characters, the combined effect of variation in two, three, or four characters. From this treatment of the data it is also obvious that more than four dimensions (or characters) may be considered simultaneously.

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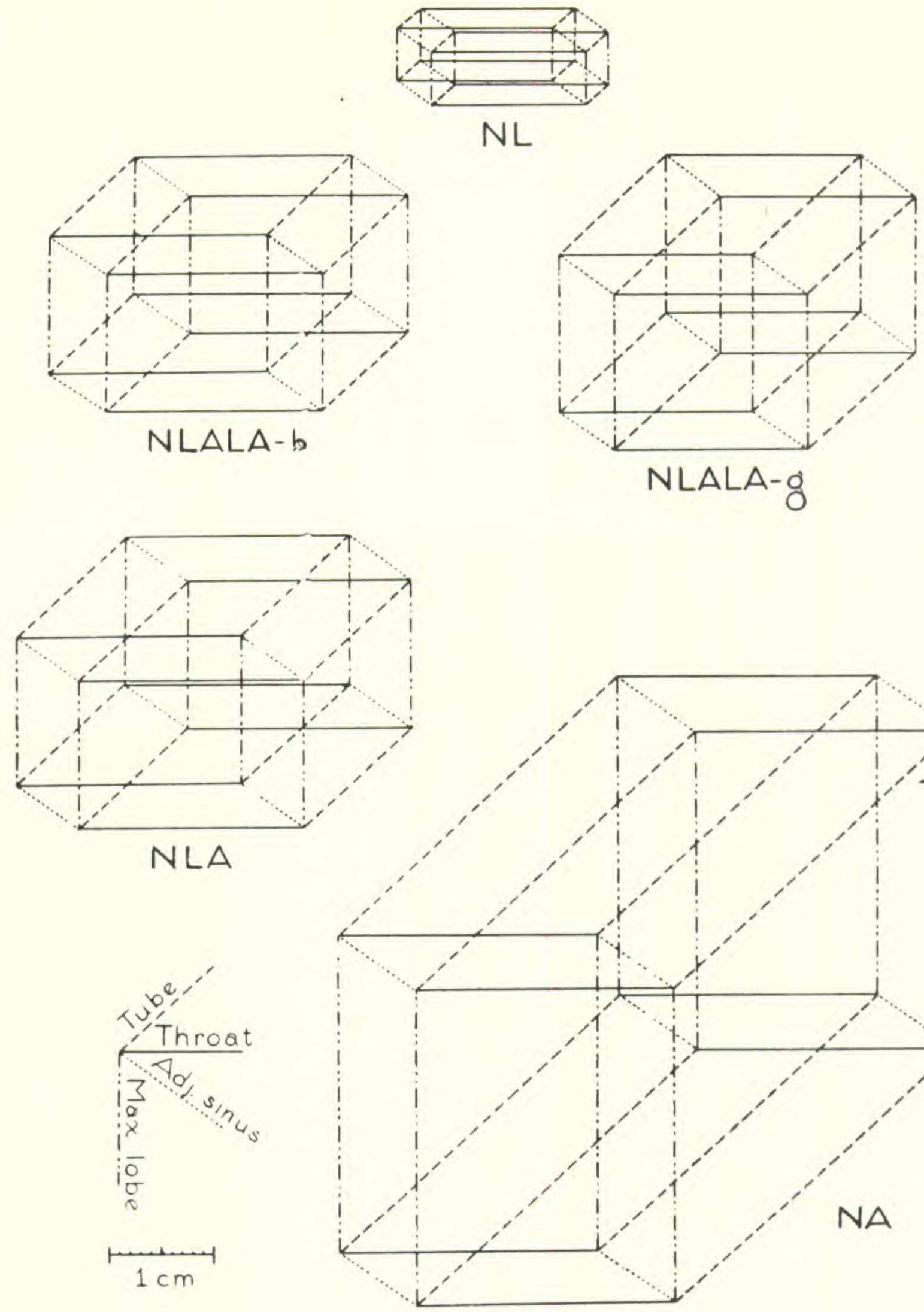

Fig. 2. Fourth-dimensional representation of species crosses in *Nicotiana.*

NL — *Nicotiana Langsdorfii*: throat, 1.5 cm.; maximum lobe, .5 cm.; adjacent sinus, .5 cm.; tube, .4 cm.

NA—*N. alata:* throat, 2.5 cm.; maximum lobe, 3.0 cm.; adjacent sinus, 1.1 cm.; tube, 4.9 cm.

NLA — F-1 generation: throat, 2.15 cm.; maximum lobe, 1.4 cm.; adjacent sinus, .9 cm.; tube, 1.9 cm.

NLALA-b — Family b of F-2 generation: throat, 2.1 cm.; maximum lobe, 1.3 cm.; adjacent sinus, .8 cm.; tube, 1.5 cm.

NLALA-g — Family g of F-2 generation: throat, 1.9 cm.; maximum lobe, 1.5 cm.; adjacent sinus, .8 cm.; tube, 1.9 cm.